Amphibious vehicle suspension

The present invention relates to an amphibious vehicle; and particularly to such a vehicle having at least one pair of wheels arranged to retract from road mode to marine mode.

Such a vehicle is shown in US Patent No. 5,531,179 (Roycroft). In order to improve road performance, it has been proposed to provide anti-roll bars for amphibians. However this proposal has only, so far as is known, been applied to a slow speed, low marine performance, vehicle such as the Hobbycar. This vehicle was a displacement vessel with an advertised top speed of 5 knots in water; its anti-roll bar was located outside of the hull. For high performance in the marine mode, it is necessary to reduce any external protrusions so that the vehicle can be made to plane.

When a marine vessel is designed to plane, marine handling in cornering is generally much improved if the hull has a deadrise: that is, it is angled upwards at either side from the keel, which passes along the longitudinal centre line of the vessel. Such a hull profile will inevitably raise the centre of gravity of the vessel when compared to a flat bottomed hull. When such a vessel is an amphibious vehicle with alternative use on road, the raised centre of gravity may markedly increase roll angles on the road, unless an anti-roll bar is fitted.

As has been proposed in the Roycroft vehicle mentioned above, the front and indeed also the rear road wheels (it is a four wheeled vehicle) are arranged to fold upwards substantially above the waterline in marine mode. That is, the wheels when retracted are laterally closer to each other, than when protracted in road mode. There is therefore a problem when linking the wheel suspensions by an anti-roll bar, as to how to fold and retract the wheels. A conventional anti-roll bar would inhibit movement of wheels on opposite sides of the body towards each other.

According to the invention, an amphibious vehicle having a hull is provided with at least a pair of wheels on opposite sides of the vehicle, each wheel of the pair being mounted by means of a suspension to the body of the vehicle, the suspension being so

arranged as to be enabled by retraction means to retract its wheel upwards into a stowed position, an anti-roll bar being mounted so as to connect the suspensions on opposite sides of the vehicle, the anti-roll bar being further arranged to partially rotate from a first position in road mode to a second position in marine mode.

In this context, the term "partially rotate" refers to rotation through an arc of less than three hundred and sixty degrees; as opposed to a part only of the bar rotating.

The suspension may be a front or a rear suspension. The wheels may be steered, passively steered, or not steered; and may be driven wheels.

The ability for the anti-roll bar to rotate enables the anti-roll bar to be mounted within the hull of the vehicle so that it does not cause water flow problems below the hull in the marine mode. Preferably, the anti-roll bar is mounted in at least one bearing within the vehicle, so that when the wheels are retracted, the anti-roll bar rotates about a single axis. This provision ensures the anti-roll bar protrudes through the hull of the vehicle through a minimum sized opening. In turn, this ensures that sealing arrangements between the hull and the anti-roll bar are kept as simple and as cost effective as possible.

A preferred form of seal for the anti-roll bar is mounted inside the hull, so as to ensure an optimum hull shape. To achieve an adequate water seal in a position where the anti-roll bar is usually above the water line when the vehicle is planing, the seal has an internal circular lip portion extending outwardly from an inner part of the seal, the lip portion being arranged to seat against the bar; or against a ring or a collar around the bar. Water pressure mostly caused by the vehicle slamming on the water when planing is therefore arranged to act on the lip to improve sealing.

Alternatively, the seal may be mounted outside the hull, with the internal circular lip portion extending inwardly from an outer part of the seal. This may improve seal performance by allowing water pressure to act over a greater area, but requires a different hull shape to package the seal effectively without leaving it open to damage by foreign objects.

The invention will now be described with reference to the accompanying drawings in which:

Figure 1 is a front view of the Roycroft amphibious vehicle shown in US patent no. 5,531,179, with the front wheels in road mode, and in broken lines in marine mode;

Figure 2 is a perspective side view of a front suspension in road mode, for a planing amphibious vehicle according to the invention, modified from that shown in Figure 1;

Figure 3 is a perspective side view of the front suspension of Figure 2 in marine mode;

Figure 4 is a cross sectional front view of an anti-roll bar being part of the suspension of Figure 2;

Figure 5 is an enlarged view of part of Figure 4 showing sealing;

Figure 6 is a cross sectional front view of an anti-roll bar being part of the suspension of Figure 2, with an alternative sealing arrangement; and

Figure 7 is an enlarged view of part of Figure 6 showing sealing.

In Figure 1, Roycroft's amphibious vehicle as described in US patent no. 5,531,179 is shown with the front wheels 2 shown in unbroken lines down in road mode and at 2' in broken lines up in marine mode. The wheel bearings are also shown at 4 in the road mode position and at 4' in the marine mode position. The bottom 6 of the hull 8 of the vehicle forms a lower part of a clearly necessary watertight whole. The wheels 2 are designed and arranged to be outside the watertight area; and to fold upwards into pockets 10. This Roycroft vehicle did not have an anti-roll bar; which would have been apparently a problem to arrange since at least the wheel bearings 4' are closer together than those at 4.

In Figures 2 and 3, the suspension of the invention is shown in detail, and comprises a wheel hub plate 12 mounted for rotation on bearing component 14 known as an upright, having mountings 16 for a brake caliper (not shown). Upright 14 has a minor arm 18 extending forwardly to receive the outer end of steering link 20; and a major arm 22 extending upwardly to connect by means of a horizontal ball joint 24 with top arm 26. The top arm has a rearward extension 28 which receives part of a suspension height sensor, enabling water depth sensing as described in the applicant's co-pending GB patent application no. 0128338.1.

Supporting the lower part of upright 14 is a bottom wishbone 30, which is pivotally mounted to the vehicle body by bushes 31 for pivotal movement about axis B which intersects axis E of steering arm 32. Steering arm 32 is mounted in water tight bush 34 in bush plate 36, which is secured to the vehicle body. Also pivotally attached to the bottom wishbone 30 is piston rod 38 arranged to extend and retract along axis C from and into hydraulic cylinder 40; which is pivotally mounted about axis G to the vehicle body at pivot points 42, as described in the applicant's co-pending patent application, published as WO 02/44006. Further linked to bottom wishbone 30 by anti-roll bar link 44 is anti-roll bar 46, which is mounted for rotation about axis F in bracket 48 secured to the vehicle body as will be described below.

Top arm 26 is also pivotally mounted to the body by bushes 50 for pivotal movement about axis A, which is tilted at an angle θ from line B'; which in turn is parallel to lower pivotal axis B. θ may vary from 2° to 3°, but is typically set at about 2.4° to inhibit dive. Axis A is normally three to four degrees to the horizontal, and in this case preferably about 3.5°. Axis G is parallel to axis B, and perpendicular to axis C.

Although the suspension is here shown for a steered wheel, it may be applied to a non-steered wheel by using link 20 as a track control arm, fixed directly to the vehicle body rather than to a steering arm 32 as shown. It is also known in the automotive engineering art to use passive steering to adjust the steering angle of wheels not steered by the driver, causing the wheels to "toe in" or to "toe out". Such a system can be tuned to make chassis behaviour in cornering, in braking, or even in crosswinds, more predictable. In the case of the suspension shown in the figures, such passive steering may be introduced by careful selection of suspension geometry, and by adjustment of hardness of suspension bushes in different axes (x, y, and z – not shown). Equally, the suspension could be adapted to a driven pair of wheels by adding a driveshaft (not shown).

Turning to Figures 4 and 5, the anti-roll bar 46 is shown from the front of the vehicle; part of whose body 52 has bearing 48 arranged to pivotally support bar 46. The bar comprises a central straight portion 54 and a cranked portion 56 at each end (only the

near side end being shown). At the terminal end of each portion 56, a hole 58 is provided to attach link 44 by a pivotable connection.

In order to ensure that the bar 46 is sealed to the exterior watertight bodywork 60 of the vehicle, an elastomeric seal 62 is provided in hole 64 in the watertight bodywork. Seal 62 extends inwardly into the vehicle and engages with annular groove 66 of collar 68, which is fixed - preferably by welding – to portion 54 of bar 46. Conventionally, such a collar would be welded to the bar by tack welding only; but for waterproofing, it has been found best for marine use to weld the collar continuously all the way around the bar. Collar 68 has an outwardly facing cylindrical portion 70 which provides a secondary sealing surface to the primary sealing surface of groove 66. The seal has an outwardly directed lip portion 72, which is biased against cylindrical surface 70; so that water entering hole 64 under pressure caused by the vehicle slamming on the water at high speed tends to tighten the seal. Said seal is fixed into hole 64 by outer and inner flanged parts 74 and 76.

Collar 68 is used to provide a groove 66 for sealing purposes, but use of this collar – or a simpler ring form 78 as described below with reference to Figures 6 and 7 – is optional. To save additional parts count and the welding operations, grooves 66 could be cut straight into anti-roll bar 46 at each end. The bar would then have to be made from larger diameter stock, as its effective diameter, controlling its behaviour as a torsion spring, would be the diameter at the base of groove 66.

The cranking of portion 56 of the anti-roll bar is designed so as to be insertable through holes 64 in the bodywork 60 during vehicle assembly; avoiding the additional cost and complication of a two-part anti-roll bar. It will be noted from Figures 2 and 3 that as the wheels are retracted upwardly into a stowed position by retraction means comprising cylinder 40 and piston rod 38 (Fig. 3), the anti-roll bar 46 is caused to partially rotate from its first position in Figure 2 to its second position in Figure 3. From a static position on the road with driver only in the vehicle, the angle of rotation upwards about axis F of the anti-roll bar is between twenty seven and forty seven degrees; but preferably in the embodiment shown, about thirty seven degrees. Furthermore, anti-roll bar 46 may rotate downwards by up to eighteen degrees as the wheel droops when the amphibious vehicle is floating – usually during marine to land conversion, or vice versa.

An alternative embodiment of the sealing arrangement is shown in Figures 6 and 7. In this case, ring 78 (corresponding to collar 68 in the embodiment of Figures 4 and 5) and seal 62 are reversed in their orientation on bar 46. Ring 78 is more economical in its use of metal than collar 68, but collar 68 may support seal 62 more effectively. In the embodiment of Figures 6 and 7, bodywork 60 is cranked inwards on either side of the vehicle to protect seal 62 from foreign object damage, and to allow ring 78 to be fitted inboard of cranked portion 56 of bar 46.

As can be seen from Figure 7, in this embodiment, water pressure P would tend to force the essentially tubular section 82 of seal 62 in towards anti-roll bar 46, causing the outer end of seal 62 to lift out of groove 66, as shown at L. In this case, lip seal 72 acts to maintain the profile of seal 62 by pressing against section 80 of ring 78, maintaining the profile of section 82 to maintain the integrity of seal 62. In a further alternative embodiment (not shown), the inner end 80 of ring 78 could be built up in diameter to support section 82 directly, avoiding the need for lip seal 72.